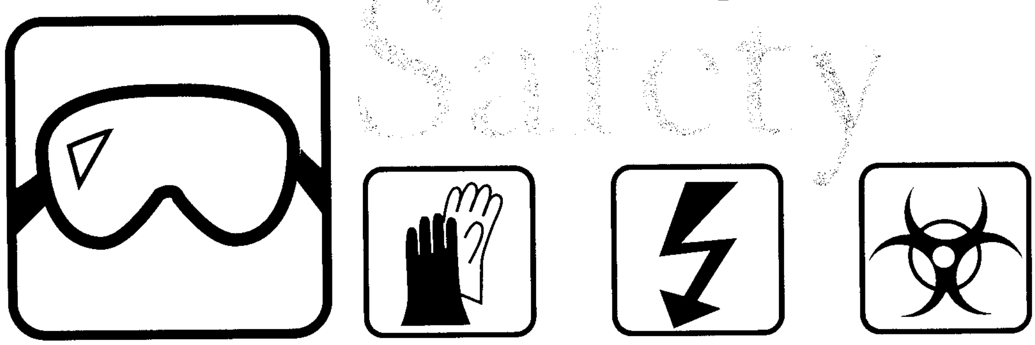
Making Sense of Safety



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An important part of the science classroom involves teaching students how to safely use tools, techniques, and procedures. As emphasized in the *National Science Education Standards*, "safety is a fundamental concern in all experiential science" and teachers must "teach students how to engage safely in investigations inside and outside the classroom" (NRC 1996, p. 44).

A teacher's most effective strategy for creating a safe lab environment is to train students to follow recommended safety procedures. To protect themselves, students must learn to wear appropriate apparel for lab work and to properly use safety and personal protective equipment. Students who understand the reasons for the safety rules and the dangers of breaking the rules can assume responsibility for their actions and realize that one careless action can endanger the entire class.

Cooperative learning activities allow students time to reflect on the implications of lab safety rules

The following activities allow students time to reflect on lab safety rules and discuss the implications of the rules through cooperative learning (for a list of safety rules, see Figure 2 in *Habits of Mind for the Science Laboratory* on page 26 of this issue). Some of the activities described in this article direct students to create learning tools that may be used throughout the year. Upon completion of a project, students should present their work and explain their reasoning to the class. When students teach content they attain a deeper understanding of the material and strive for a higher level of compliance. Additionally, student presentations allow teachers a chance to assess student understanding of the rules.

Safety contracts game

When students sign a safety contract, they indicate that they fully understand the rules. However, reading the rules to students does not ensure that they understand all of the implications. The "Why not?" game gives students the opportunity to reflect on and understand the reasoning behind each rule.

For the "Why not?" game, the teacher divides the class into three groups and the lab rules into categories such as safety equipment, safety procedures, protective apparel, and emergency actions. In turn, each group of students selects a category. The teacher states one of the rules in a selected category and asks "Why?" or "Why not?" For example, the teacher states the rule, "Always add acid to water; never add water to acid." Then, the teacher follows the rule with the question "Why?" or "Why not?" as appropriate (see sidebar "*Always* add acid to water," page 32). A student may respond, "The acid being poured is more dense than water and falls to the bottom of the container. Therefore, splashes would consist mainly of the water that was already in the beaker." Through guided discussions, students can move to more sophisticated understandings and learn important science content along the way.

Once the rule is stated, the group has 30 seconds to confer and must offer a reason for the rule at the end of this time. If the reason is valid, the group scores 10 points. A reply of "Because I'll get into trouble" is not a valid reason. If a group of students cannot think of a reason, the next group can answer the question for double points.

For advanced students, each group must answer the same question in turn, but cannot repeat another group's answer. This strategy forces students to think of three reasons behind each rule. Because the difficulty level of this advanced version of the game increases with each subsequent answer, the group providing the first reason receives 5 points, the group providing a second reason receives 10 points, and the group providing the third reason receives 15 points.

Safety mini-lessons

Although lab safety is always taught at the beginning of the course, effective safety lessons should continue throughout the school year. Safety mini-lessons should be scattered throughout the curriculum to teach proper lab techniques and emergency response prior to conducting labs.

For example, when working with acids, teachers can demonstrate the reaction that happens when acid is splashed into the eye by breaking a raw egg into a beaker. The egg yolk should be intact so that the egg whites can be clearly seen. Then, the teacher pours acetic acid or vinegar into the beaker with the egg. The acid causes the proteins in the egg white to coagulate, just as it would in a human eye. In the human eye, acid burns—aside from hydrofluoric acid—are usually nonprogressive and superficial because they "cause protein coagulation in the corneal epithelium, which limits further penetration" (Reenstra-Buras 2004).

Another example of a safety mini-lesson involves teaching electrical safety along with a lesson on electricity. This lesson can be used with physical science, physics, or chemistry curriculums. A ground fault circuit interrupter (GFCI) circuit tester can be used to check the circuits in the lab for the presence of GFCI, which provides electric shock protection. A teacher or custodian should conduct tests to prevent the circuit from being knocked out—this is not dangerous, but the circuit would have to be reset at the breaker panel or wherever the GFCI button is located. In addition to these mini-lessons, the following short descriptions provide ideas for activities that can also be interspersed throughout the science curriculum.

SCILINKS
THE WORLD'S A CLICK AWAY
Keywords: Safety in the science classroom
at *www.scilinks.org*
Enter code: TST090501

To prepare for the Luck of the Draw poster contest, the teacher writes safety rules on small slips of paper (one rule per slip), folds them, and places them in a beaker. Each group draws a safety rule out of a beaker and is given one hour to collaborate and design a poster illustrating that rule. Drawing software may be used to create the project. The following day, students present their posters and explain why they chose to illustrate the rule as they did. Posters are then displayed in the lab and the class votes on the most creative poster and the best-illustrated rule. Ribbons or certificates may be offered as prizes.

Students can also create a hypermedia project using web or presentation software to identify and illustrate lab safety rules or proper lab techniques. For example, student groups may create web pages to add to their school's science website. One group may focus on personal protective equipment, another may describe what to do in case of burns, while a third group may demonstrate proper pipetting or titration techniques. Students may also research actual cases involving personal injury in the lab and include them in the presentation.

This project should take students three class periods to complete: one to design and plan their project and research their topic, a second to develop the project, and a third to edit and present the final product. These projects may be used as teaching tools when the lab procedure is conducted again.

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CAUTION

Always add acid to water.

There are several important reasons adding acid to water and not the reverse should always be used to create acid dilutions. Teaching students these reasons can provide a way to integrate chemical content understanding with safety lessons.

When considering this rule, the most important example is sulfuric acid. This acid generates a large amount of heat when dissolved into water, about 97,000 J/kg of the acid. Most of this heat comes from the hydration of the acid's hydrogen ions as they quickly bond to water molecules. This heat is the problem: It can cause splattering or even boiling of the acid-water mixture, potentially splattering the mixture onto nearby hands and into eyes.

How does adding acid to water help prevent this? First of all, adding a small amount of acid to a larger amount of water immediately dilutes the acid and allows the heat generated to be dissipated throughout the mixture (constant stirring helps this). Second, concentrated sulfuric acid is 1.8 times denser than water and will sink to the bottom of the container, diluting and mixing as it goes down. This also helps to dissipate the heat. Finally, the larger specific heat capacity of water (4.18 J/g° to sulfuric acid's 1.42 J/g°) makes water a better heat sink to absorb the energy produced.

Now imagine the opposite and unsafe situation, adding water to acid. At the beginning of the dilution, a smaller amount of water is added to a relatively larger volume of acid, quickly creating a very concentrated solution. Instead of mixing quickly, the less dense water floats above the acid, creating an interface where a large amount of heat is generated. There is little water available to absorb the heat, and the mixture boils and splatters acid everywhere. It's a recipe for disaster.

Why not use this type of example to teach about the chemistry behind this and other safety rules, rather than a simple admonition to "follow the rules?" Students will learn important science principles and achieve a better understanding of the reasons behind the rule. Better student compliance with the safety rule will be an important byproduct.

Another consideration is to only purchase diluted acids in the concentrations needed. Although this type of purchase is a little more expensive, it is definitely safer, valuable prep time will be saved, and large quantities of concentrated acids will not need to be stored.

What's wrong with this picture?

One way for students to learn about unsafe lab conditions is by identifying the broken rules in drawings. Groups of students create their own sketches of individuals conducting labs and switch with other groups to find the rules that have been broken. Drawings may be evaluated by peer groups using a rubric that identifies the number of rules broken in the drawing and the clarity of the hazardous situations in the drawing.

Character rule-breakers

Another way to help students identify unsafe procedures is by having them write stories or scripts depicting cartoon or television characters in unsafe situations. Sample stories can be downloaded from the internet by typing the key word "science safety rules" in a search engine. Example stories depicting SpongeBob SquarePants in unsafe lab situations can be found on The Science Spot website at ***http://sciencespot.net/Media/scimthdsafety.pdf***. Assessment may involve students switching stories with other students who then try to identify the broken rules.

The absent-minded professor skit

Students may videotape a group of teachers, classmates, or a drama class performing a skit of an absent-minded professor who attempts to conduct an experiment but forgets relevant safety procedures and equipment. To ensure the safety of individuals in the skit, only water is used to represent "hazardous chemicals." Food coloring may be added for visual aid. As the videotape is shown to the class, students try to identify the broken rules. Students complete a T-chart in which the problem situation in the skit is identified on the left side of the chart and the corresponding broken rule appears on the right side of the chart.

Movie makers

Before conducting new lab or safety procedures, student groups can research proper techniques and, with the help of the instructor, practice the procedure in lab and demonstrate it for the class. Each presentation is videotaped using a digital camcorder and transferred to a computer using the appropriate cable (some equipment requires a USB while others use a firewire/IEEE 1394 cable). Students may then use movie software—such as iMovie, MovieMaker, or equivalents—to create their own movies and post them to a web page. Teachers of other science classes could access these movies to review safety with their students.

What if safety scenarios?

For this activity, the teacher distributes a card describing a different scenario to each group of students. For example, a scenario may involve one of the lab partners knocking over a beaker of hydrochloric acid that spills on a student's arm. Students develop a plan of action for each scenario. They must take into account their location in the lab and the safety equipment immediately available.

The students' plan should state that in response to this injury, students choose the closest source of water, such as

the sink, the safety shower, and eyewash—a tepid water eyewash should be a priority, located within 10 seconds access from any part of the lab—to wash the acid from the injured student's arm. Plans must also include applying large amounts of tepid water to the injured arm for at least 15 minutes, followed by neutralizing the acid with a paste of sodium bicarbonate (external use only), and seeking medical attention.

The plan should also state that in response to the spill, students should first contact the teacher and then attempt to contain the spill with an absorbent material such as sand, kitty litter, spill pillows, or even paper towels (depending on local department, school, or district spill policy). Students should leave the actual cleanup of the spill to the teacher or custodial staff (again, depending on the local spill policy), who will neutralize the acid and dispose of the waste properly.

Teachers can design a safety scavenger hunt specifically for their laboratory areas so students learn where equipment is located and how to use it. Some items to include are specific information from chemical labels, Material Safety Data Sheets (MSDS), and the location and use of the fire extinguisher, eyewash and safety shower, fire blanket, sand buckets, first-aid kit, spill control kit, personal protective equipment, and sterilizing cabinet (see "MSDS" below). Each item should have a question associated with it. For example, "What is the temperature of the water from the eyewash?" or "Why might you use the fire blanket or sand instead of the safety shower to put out a fire?"

In the five minutes at the end of lab, after students clean up and are waiting for the bell to ring, drills of safety procedures may be conducted. An example drill may involve the following situation, "What would you do if you reached over a Bunsen burner and your sleeve caught on fire?" Acting out the mock scenario, lab partners work cooperatively to solve the problem. Students close to the fire blanket may grab it to suffocate the flames while those students farther away from the fire blanket may choose the old standby: stop, drop, and roll.

MSDS.

No shipment of chemicals should be accepted unless it contains the appropriate MSDS. Federal and many state laws now require that MSDS's be available at all times for every chemical used or stored. A backup copy of each sheet should be stored at a central location to be available to first responders in cases of fire or other emergency. For a list of web links to the MSDS sheets of common cleaning supplies, visit the online version of this article at *www.nsta.org/highschool#journal.*

Always communicate safety

Some of the activities just listed may be completed outside of the classroom or assigned as extra credit. Projects may also be completed in conjunction with other classes to allow opportunities for integration with English, media, computer, or vocational courses. In addition to teaching safe practices, science instructors should communicate safety throughout labs by

- displaying student work as a reminder of safety,
- instructing students how to read chemical labels and MSDS's,
- posting lab rules and emergency numbers,
- developing and practicing an emergency action response plan,
- clearly identifying safety equipment and keeping maintenance logs that indicate the working status of equipment,
- properly storing chemicals by compatible families in a locked storage room (no student access!), with up-to-date inventories and MSDS's, and
- complying with practices outlined by the school's Chemical Hygiene Plan (if this is required by the school's district or state) and other safety protocols.

Science labs provide wonderful opportunities to teach students respect for chemicals and equipment. Students learn where to find information regarding potential hazards and how to protect themselves. Whether they are working with corrosives in the lab, bacteria in biology class, cleaning and lawn chemicals at home, pendulums in the physics classroom, or flammable gases in shop class, students will learn to be cognizant of safety in their environment.

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